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STORAGE OF EXPLOSIVES IN UNDERGROUND MINES OF THE LAKE SUPERIOR DISTRICT

BY

FRANK E. CASH

I.C. 7343,
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INFORMATION CIRCULAR

UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

STORAGE OF EXPLOSIVES IN UNDERGROUND MINES OF THE LAKE SUPERIOR DISTRICT[1]

By Frank E. Cash[2]

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[2] Supervising engineer, Health and Safety Branch, Bureau of Mines, Duluth, Minn.

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INTRODUCTION

Large quantities of explosives are consumed in the underground mining of ores in the Lake Superior district. Because of the recognized danger of accidentally releasing the potential highly destructive forces contained, the safest possible procedure in the transportation, storage, and use of explosives is necessary.

Underground magazines recently constructed in the district give evidence of the earnest desire of the mine operators to incorporate all possible safeguards in the storage of explosives, including a careful choice of location and arrangement in the plan of the magazine.

Scope

This discussion is confined to descriptions of locations and arrangements of explosives magazines constructed in underground iron mines of the district in recent years. No attempt is made to describe the many phases and practices involved in the transportation, storage, and use of explosives in a producing district as large as this. However, brief descriptions are given of practices at some of the mines in transporting explosives from the surface to the underground magazine.

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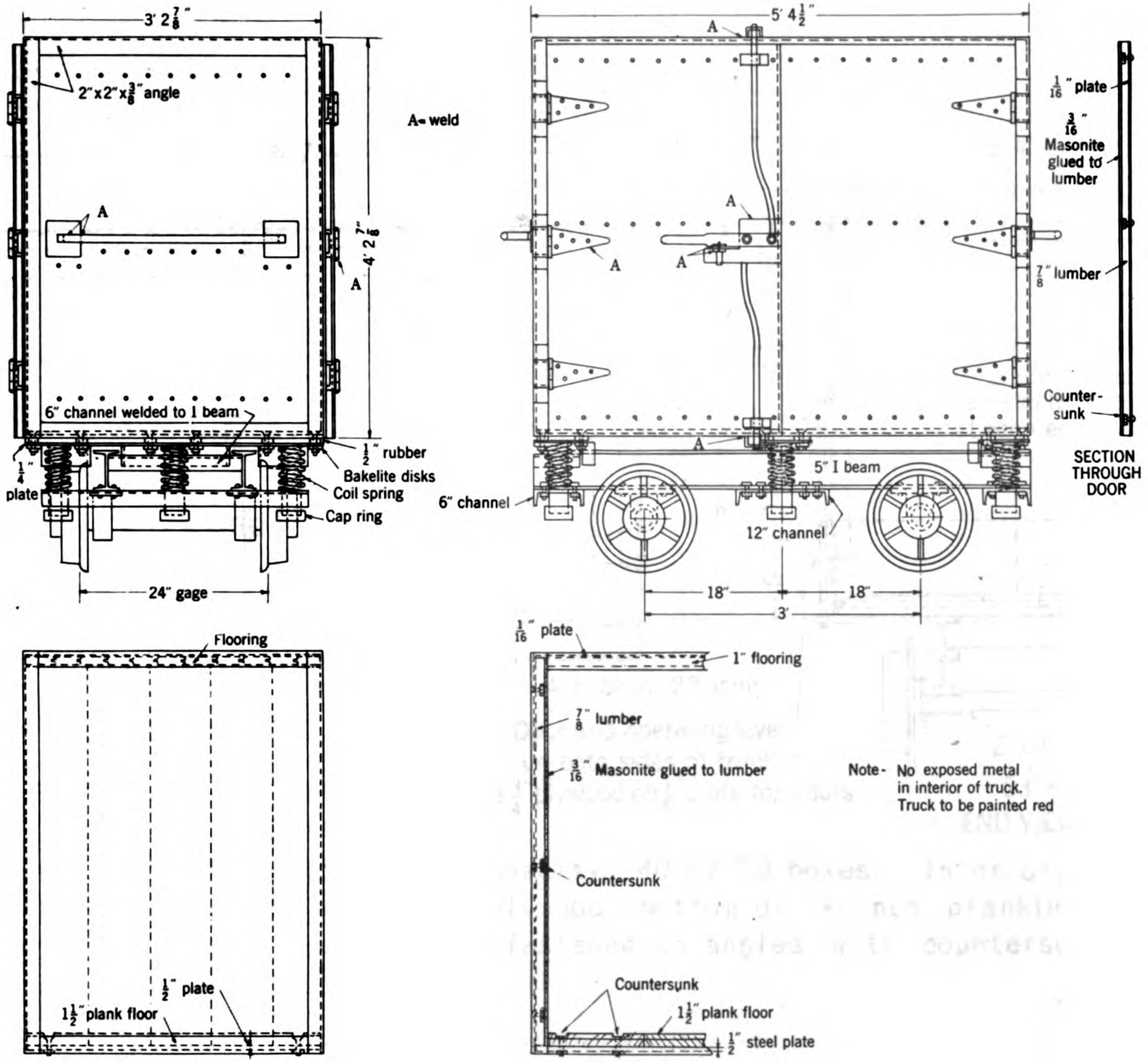

FIGURE 1.– Underground "powder" truck; capacity, 40 boxes.

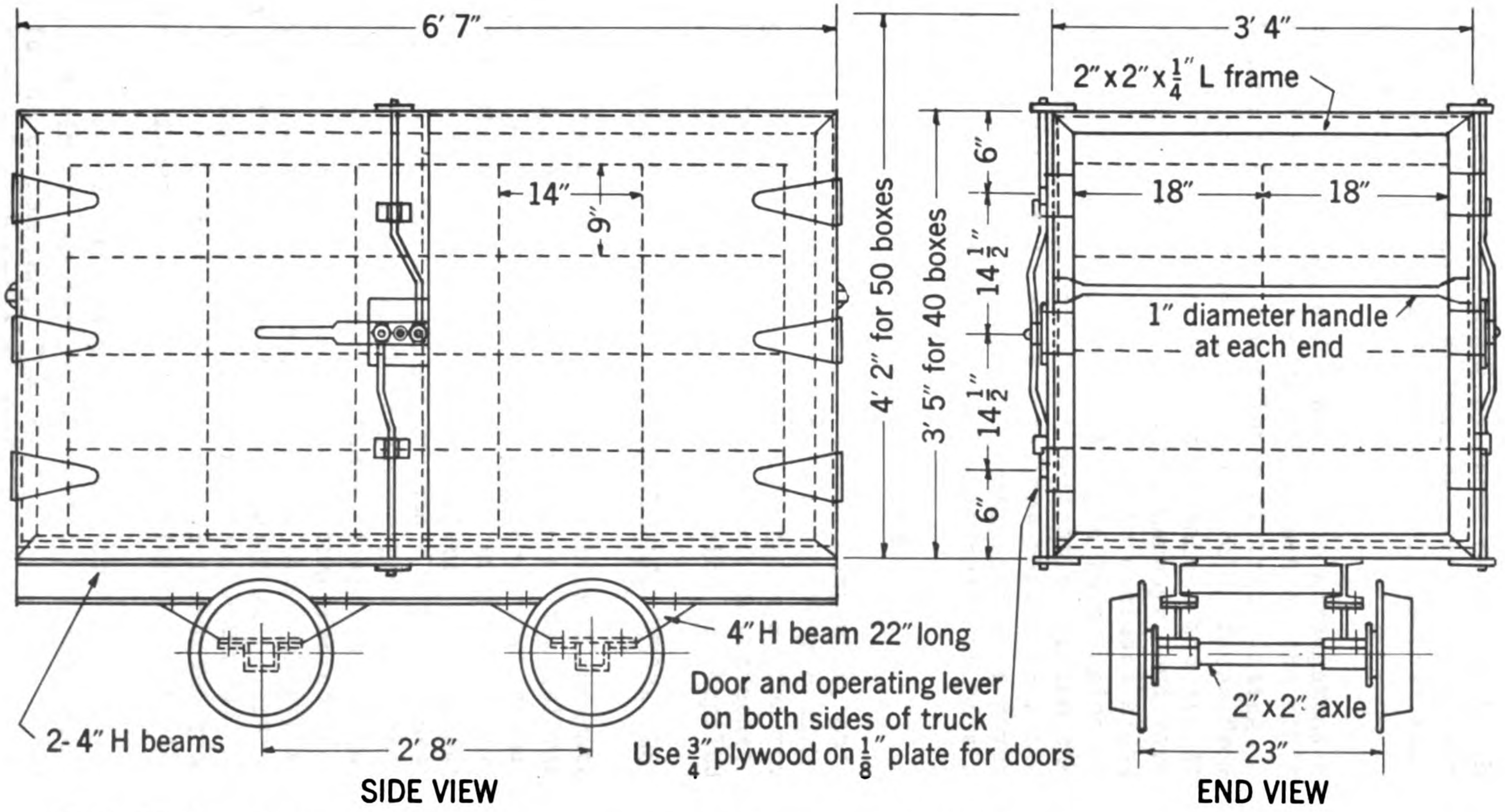

FIGURE 2.- New "powder" truck; capacity, 40 or 50 boxes. Interior, top, and ends constructed of ¾-inch plywood, bottom of 1½-inch planking covered with ¾-inch plywood; plywood fastened to angles with countersunk bolts.

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Not all of the magazines in the underground mines of the district are as well located and arranged as those described in this report, but 23 out of 25 magazines known to have been constructed within the past 2 years are considered to be reasonable safely located and more than ordinarily well-arranged.

In choosing the sites and planning the arrangement of these 23 magazines, consideration was given to the extent of the mining areas involved and the distances to them, convenience of transporting explosives from the surface to the magazine and to the working faces from the magazine, ventilation of the magazine, and the distances and directions from electrical conductors, shafts, haulageways, manways, and working places. Locations chosen for the magazines were in secluded areas where the drift approaches to the magazines provided angle turns which would lessen the destructive force of any accidental detonation of the magazine contents before these forces would reach locations more vulnerable to loss of life and the operation of the mine. This explanation is given to define use of the terms "well-located" and "well-arranged" in this report.

Acknowledgments

The courtesies of the various mining companies, and the assistance of the following members of the Health and Safety Branch are gratefully acknowledged: Ernest W. Johnson, mining engineer, for review; Max S. Peterson, mining engineer, for sketches and photographs; and Ellen M. Lundquist, clerk, for editing the information as compiled.

TRANSPORTATION OF EXPLOSIVES AND DETONATORS

The explosives and detonators are delivered separately by the manufacturer to the mine in trucks. Frequency of the deliveries varies from once a day to once a week, depending on requirements and the time most convenient to the mine operation and to a smaller extent the vendor. The explosives, in their original containers, are unloaded from the delivery truck and loaded on the mine cage or into a safely constructed explosives car, which is then pushed on the cage and lowered to the level containing the explosives-storage magazine. Cases of explosives, which are loaded directly on the cage on the surface, are transferred to an explosives car to be conveyed to the magazine. The cars are either pushed by hand or hauled by electric locomotive to the magazines. Electric power is cut off in the haulage drift when the car is hand-pushed. When hauled by an electric locomotive, two empty cars and an insulated coupling intervene between the enclosed and insulated explosives car and the locomotive.

Figures 1 and 2 show details of construction of two "Powder trucks" having bodies similar in design, without couplings, and with a handle on each end for hand tramming. The chief differences in design are that the truck in figure 1 is mounted on springs and has one-half-inch rubber insulation between the truck and body. Both have steel bodies which are lined with three-quarter-inch plywood, leaving no inside exposed metal.

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Two cars which are used for transporting explosives are shown in figures 3 and 4. A sturdy car, constructed of iron and wood, is shown in figure 3; it has slatted ends, tight floor and sides, a tight-fitting hinged top with a means of fastening provided, and no metal exposed inside. This car is loaded on the surface, hand-pushed on the cage, lowered to the magazine level, and hauled by an electric locomotive to the magazine site. Figure 4 pictures a car similar in design and construction to that just described, except that it has closed ends and is used only for transporting explosives from the cage at the shaft station to the magazine. An insulated coupling is used between the explosives car and the next car in the electric-locomotive train. Figure 5 shows a flat-topped truck used for transportation of explosives inside a magazine.

UNDERGROUND EXPLOSIVES MAGAZINES

The majority of the approximately 40 operating underground iron-ore mines in the Lake Superior district store explosives underground in a single magazine; a few have two, and some three, magazines, usually located on different levels of the mine. Depending largely on the frequency of deliveries and quantities of explosives used, from 500 to 5000 pounds of explosives are stored. The detonator magazines may contain from 1,000 to 10,000 detonators. The fuse is stored with the detonators.

Location and Arrangement

In recently constructed magazines, the aim has been to select sites consistent with future mine-development plans located at a safe distance from shafts, working place, haulageways, travelways, and electrical conductors; on return air; and with a barricade consisting of not less that 25 feet of rock or ore in place between the explosives and the detonator magazine. Care has also been taken to provide for one or more right-angle turns between magazines and places where men travel or work.

Typical arrangements at magazines built during the past 2 years are shown. Although each sketch pictures a specific magazine with its own salient features, it may be typical of the arrangements and locations of magazines in several mines.

All of the magazine sites are in relatively dry locations and so graded that water will drain away from the magazine. The lighting arrangements are similar in that the wiring is in grounded conduit, vaporproof-type fixtures are provided, and switches are located outside the magazine. Where added ventilation is needed, it is provided by a tube-blower fan located in the ventilating current with the tubing extending into the magazine. Moisture conditions occasionally make heating necessary in the detonator magazines; this is accomplished by blowing preheated air into the magazine or locating a protected electric space heater inside the magazine.

To prevent fuse or detonators from coming in contact with the heater, a wire screen is provided far enough away so the screen will not become warm enough to damage or ignite fuse or explode the detonators. The protecting wire used has a mesh size too small for fuse or detonators to penetrate to the heating element.

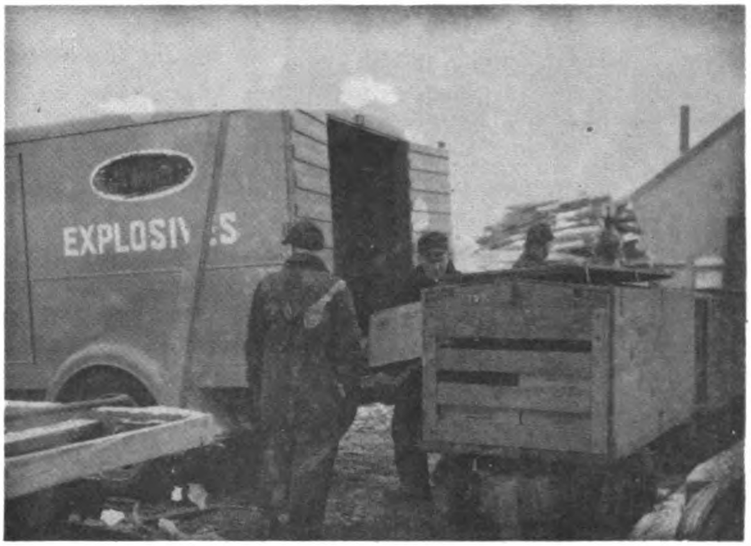

FIGURE 3.- Explosives car: Surface to magazine.

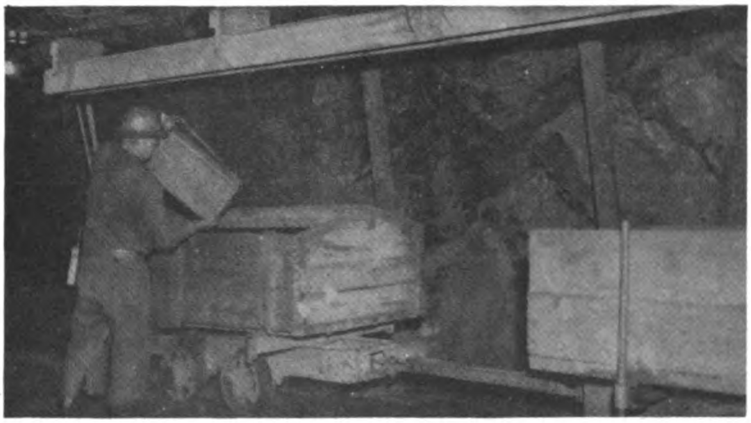

FIGURE 4.- Explosives car: Cage to magazine.

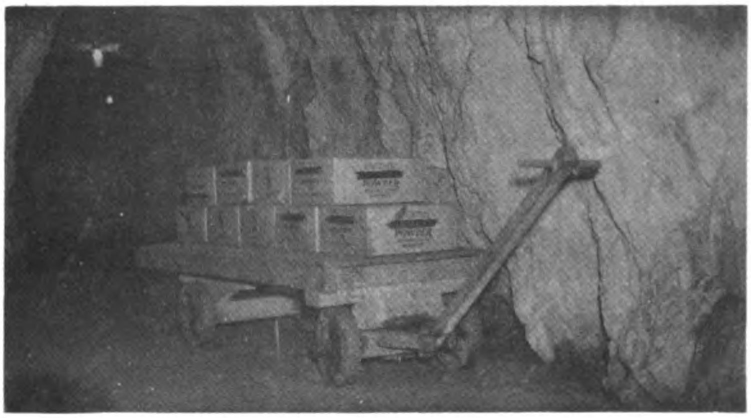

FIGURE 5.- Car for transportation of explosives inside magazine.

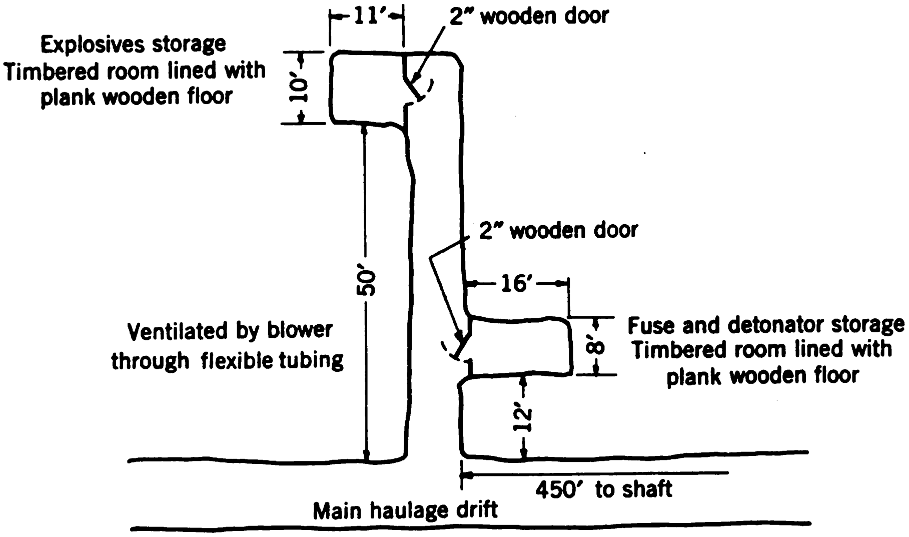

FIGURE 6.- Explosives magazines: Excavation in rock requiring support; vaporproof-type electric fixtures.

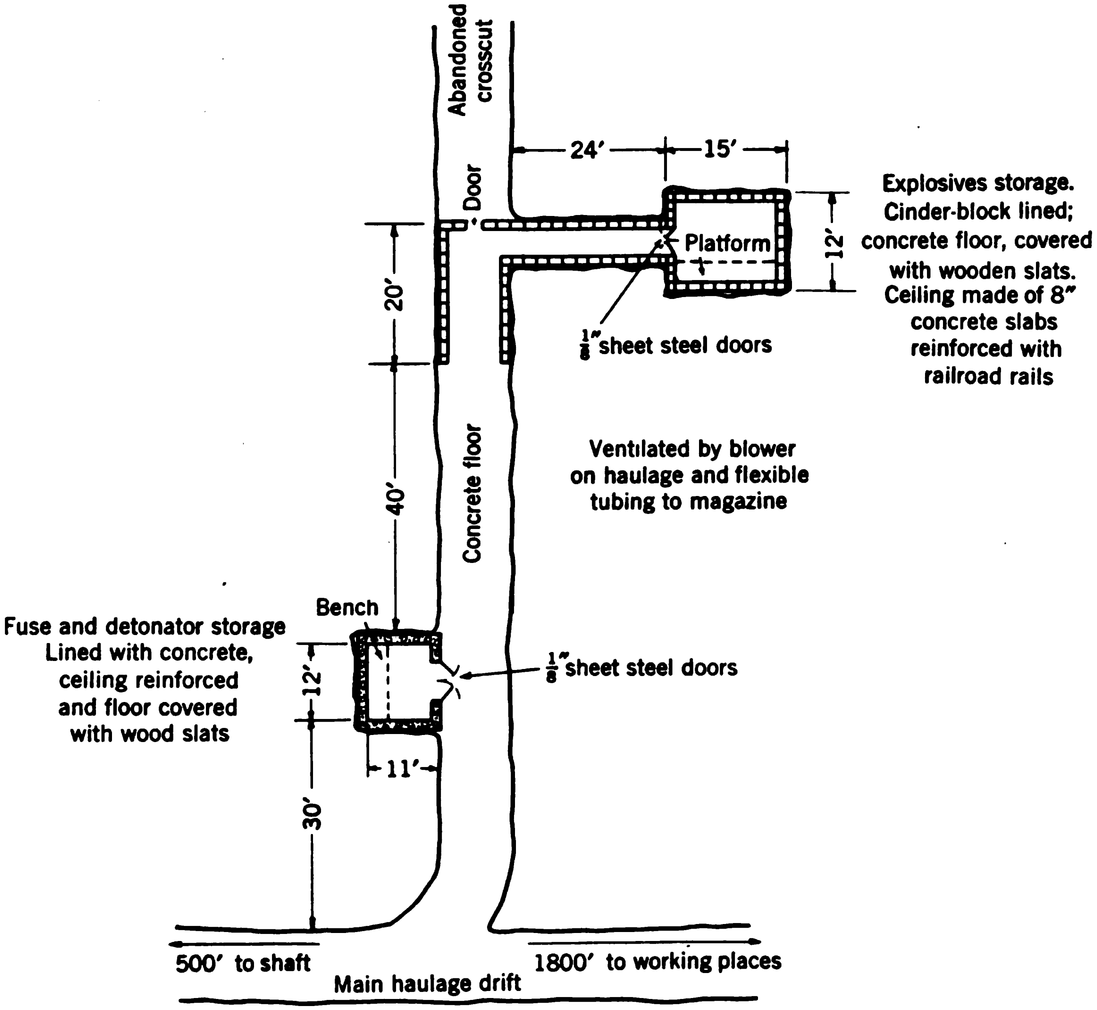

FIGURE 7.- Explosives magazines: Entire excavation in rock between shaft and orebody; no timber required.

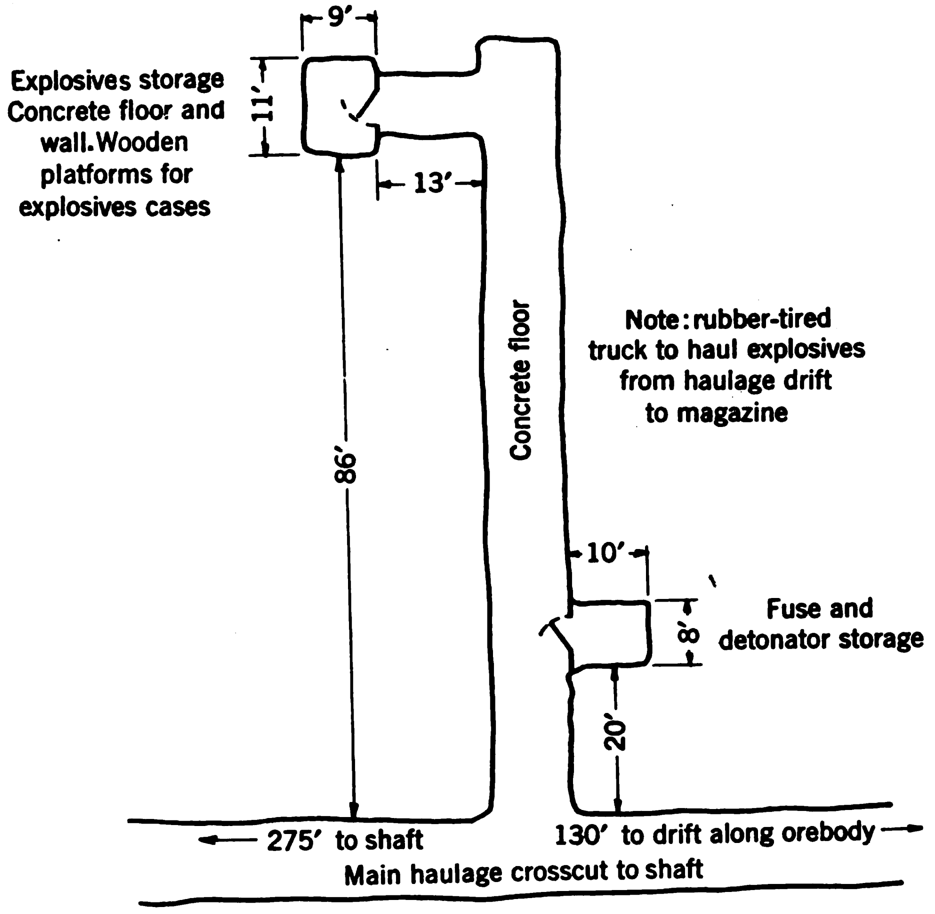

FIGURE 8.- Explosives magazines: Entire excavation in rock; vaporproof-type lighting fixtures.

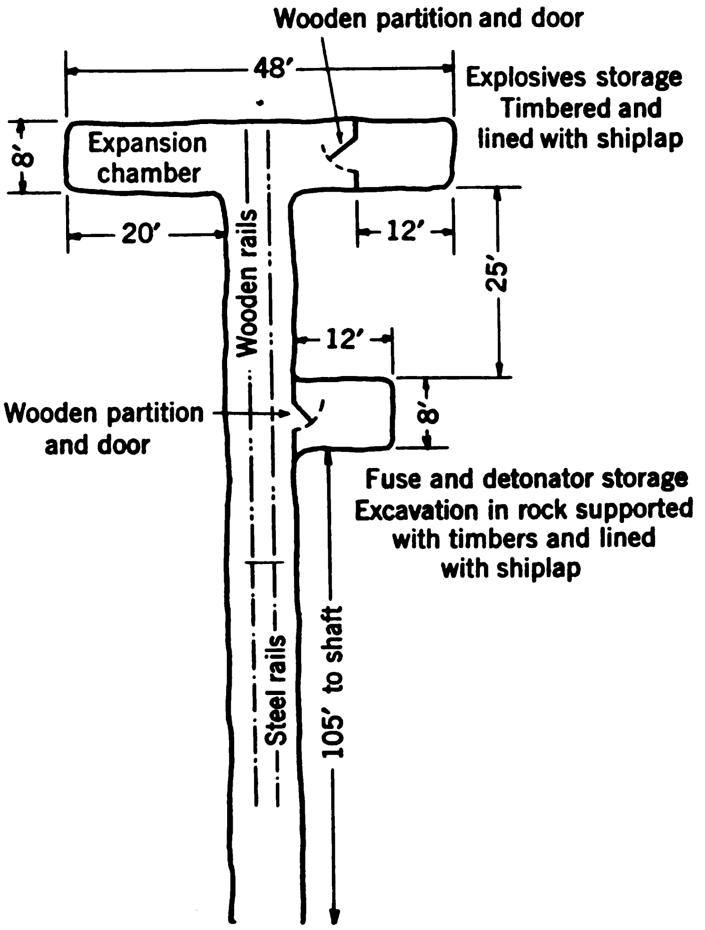

FIGURE 9.- Explosives magazines: Vapor proof-type lights; switches located outside.

In figure 6, the magazine is 450 feet from the shaft in a timbered drift in a slate formation at a right angle to the main haulage drift. The fuse- and detonator-storage and explosives-storage magazines are, respectively, 12 and 50 feet from the haulage drift. Each magazine is at a right angle to, and on an opposite side of, the cross-cut. They are floored and lined with plank, and each is provided with a 2-inch wooden door. The magazines are ventilated by a blower fan in the haulage drift and 3-inch pipe. The electric conductors for lighting are in conduit, vaporproof-type fixtures are provided, and the control switch is at the turn of the main haulage drift. The explosives are carried from the main haulage drift to the magazine.

In figure 7, the magazine is 500 feet from the hoisting shaft and 1,800 feet from the nearest working place in an untimbered, abandoned rock crosscut at a right angle to the main haulage drift. The detonator and the explosives magazines are, respectively, 30 and 126 feet from the haulage drift. Each storage is at a right angle to, and on an opposite side of, the crosscut. The entire crosscut and the magazines have concrete floors, and each magazine has a steel door and a reinforced-concrete ceiling. The walls in the detonator magazine are of concrete, and those in the explosives magazine are of cinder block. The crosscut is bulkheaded inby the explosives magazine, and the stopping contains a steel door for emergency travel. The crosscut is ventilated by a blower fan in the haulage drift through flexible tubing which discharges air just outside the explosives magazine. The light wiring is in conduit, vaporproof-type fixtures are provided, and the control switch is between the detonator magazine and the haulage drift. The explosives are carried into the magazine and stored on a platform.

In figure 8 the magazine is in an untimbered rock drift, 275 feet from the hoisting shaft and 130 feet from the orebody. The drift is at a right angle with the main-haulage crosscut. Both magazines have concrete floors. The detonator and the explosives magazines are, respectively, 20 and 86 feet from the haulage crosscut. Explosives are transported from the explosives car in the crosscut to the magazine on a flat wooden truck equipped with rubber-tired wheels, and are stored on wooden platforms. The light wiring is in conduit, vaporproof-type light fixtures are installed, and the control switch is in the main-haulage crosscut.

In figure 9, the magazines shown are in right-angle offsets from a projection of the main haulage drift, on the side of the shaft away from the orebody. The detonator magazine is 105 feet from the shaft, and the explosives magazine is 25 feet beyond that. Both magazines are timbered and lined with plank. The explosives are stored in one end of a "T" drift 48 feet in length. If stored explosives are accidentally detonated, the other end of the "T" drift would serve as an expansion chamber to absorb some of the concussive forces generated and thereby materially lessen the otherwise devastating effect along the drift and at the hoisting shaft. There is no trolley-wire installation in the drift on the explosives storage side of the shaft. A steel track is installed to within 20 feet of the detonator magazine, and a wooden track extends to the magazines. Explosives are lowered to the magazine level in a car on the cage, and the car is pushed by hand to the explosives magazine and unloaded. Light wiring is in conduit, vaporproof-type light fixtures are installed, and the control switches are in the drift outside of the detonator magazine.

In figure 10, a magazine arrangement is shown which has two advantages over that shown in figure 6; one is that an additional right-angle turn is provided, and the other is the increased distance from the hoisting shaft. The drift and the magazines are timbered and lined with wood, and have wooden floors. The light wiring is in conduit, vaporproof-type light fixtures are provided, and the control switch is at the turn from the shaft tail-track drift. The explosives are carried from this tail-track drift into the magazine.

In figure 11, the magazine is approximately 400 feet from the shaft and 300 feet from the nearest working place. The "T" drift, which is at a right angle with the haulage drift, is in the ore formation, is closely timbered, and has a wooden floor. The detonator and explosives magazines are, respectively, 30 and 65 feet from the haulage drift. Both magazines are lined with wood and have wooden floors. The expansion chamber shown would serve to lessen the destructive effect of the forces released in the event of an explosion in the magazine. The magazines are lighted with vapor-proof-type fixtures, conductors are in conduit, and the switches are in the drift a short distance from the detonator magazine.

In figure 12 the magazine is in a gunited rock crosscut which is at a right angle with a main-haulage drift about 800 feet from the hoisting shaft and 730 feet from the nearest working place. The detonator and the explosives magazines are, respectively, 30 and 65 feet from the haulage drift. The haulage drift is widened at the entrance to the magazines, and the actual entrance is closed with a Dutch door, the bottom half being kept closed and used as an issuing counter, the top half being left open while the magazine is attended. The magazines are ventilated by means of a blower fan in the haulage drift, which forces air through a rigid pipe below the concrete floor, discharging through a wooden conduit extending 6 feet above the floor at the inner face of the explosives magazine. The light wiring is in conduit, vaporproof-type light fixtures are provided, and the control switch is outside, near the haulage drift. Explosives are transported in an explosives car from the surface to the entrance door leading to the magazines; here they are transferred to a truck that is all wood, except for a brass hinge pin, and hand-trammed into the magazine, where they are stored on wooden platforms.

In figure 13, the magazine is approximately 600 feet from the shaft and 1,000 feet from the nearest working place. A gunited rock-drift airway, which is at a right angle to the haulage drift, was widened from a 10-foot to a 16-foot width, and spaces for the magazines are cut at a right angle to the airway drift. The detonator and the explosives magazines are, respectively 61 and 111 feet from the haulage drift. Doors to the magazines are constructed of 3-inch planks, and their frames are set in tile partitions.

The magazine sketched in figure 14 is in a rock drift about 1,500 feet from the shaft and 400 feet from the nearest working place. Both the drift and magazines have concrete floors and gunited walls and roofs. The detonator magazine is an 8- by 12-foot chamber, 21 feet from the haulage drift. The explosives magazine is a 10- by 16-foot chamber on the opposite side of the drift and 75 feet from the haulage drift. The light wiring is in conduit,

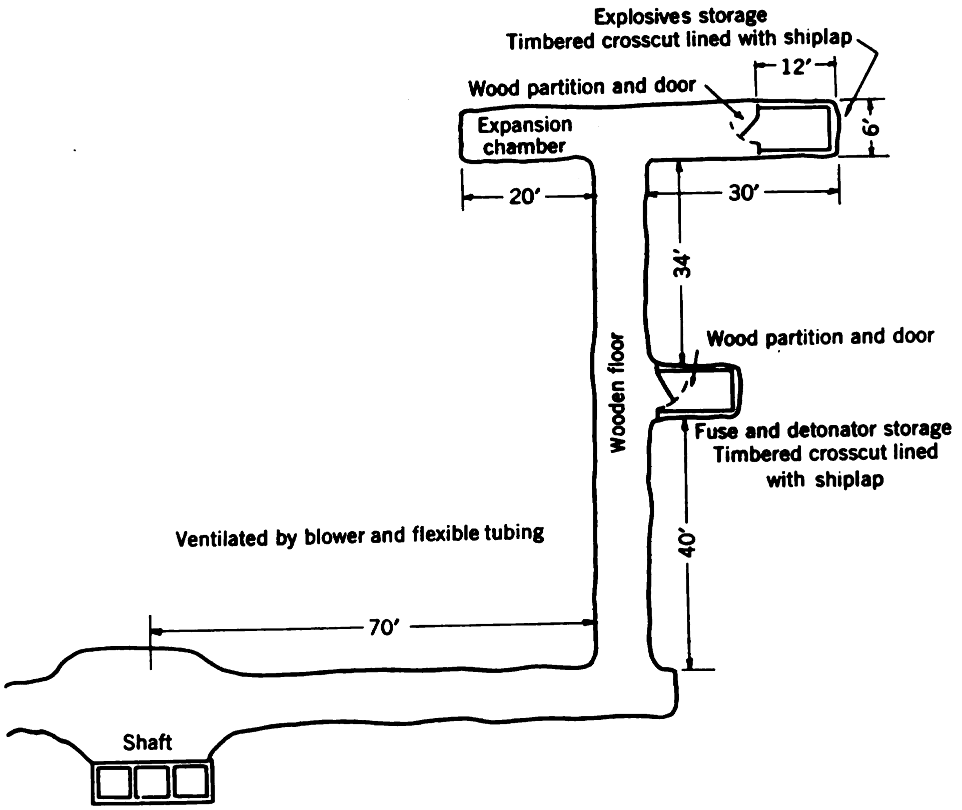
Explosives storage
Timbered crosscut lined with shiplap
12'
Wood partition and door
Expansion chamber
6'
20'
30'
34'
Wood partition and door
Wooden floor
Fuse and detonator storage
Timbered crosscut lined with shiplap
Ventilated by blower and flexible tubing
40'
70'
Shaft

FIGURE 10.- Explosives magazines: Excavation in slate, which requires timbering; vaporproof-type fixtures; electric conductors in conduit.

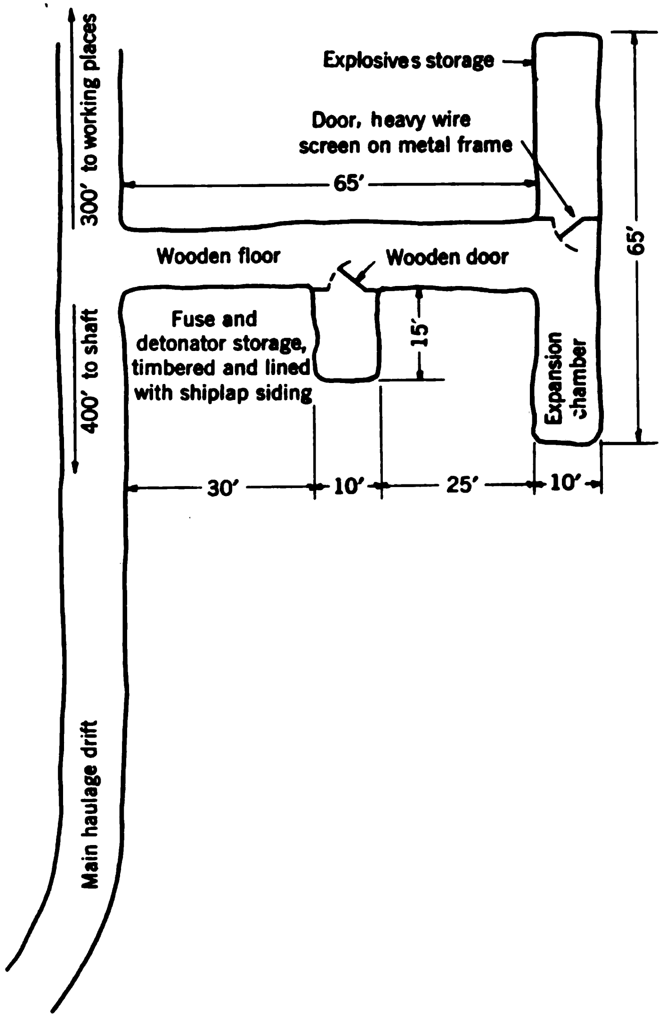

FIGURE 11.- Explosives magazines: All workings shown in ore formation, requiring heavy timbering; vaporproof lights; wiring in conduit.

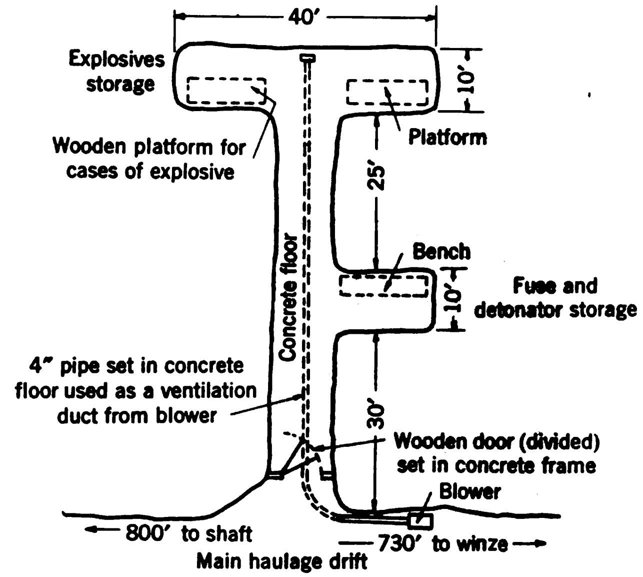
40′
Explosives storage
10′
Platform
Wooden platform for cases of explosive
25′
Bench
Concrete floor
10′
Fuse and detonator storage
4″ pipe set in concrete floor used as a ventilation duct from blower
30′
Wooden door (divided) set in concrete frame
Blower
800′ to shaft
730′ to winze
Main haulage drift

FIGURE 12.- Explosives magazines: Entire excavation in rock, requiring no support; walls and back gunited; lighting by vaporproof lights; wiring in conduit; switches located outside.

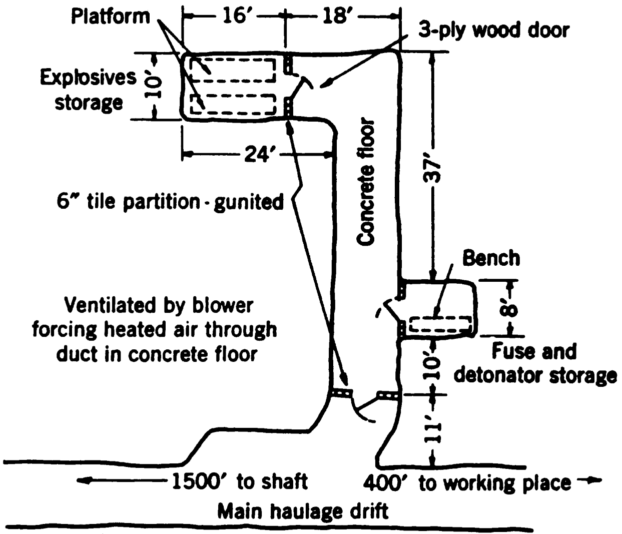

FIGURE 14.- Explosives magazines: Excavation in rock, requiring no support; back and walls gunited; vapor-proof-type electric lights; wiring in conduit.

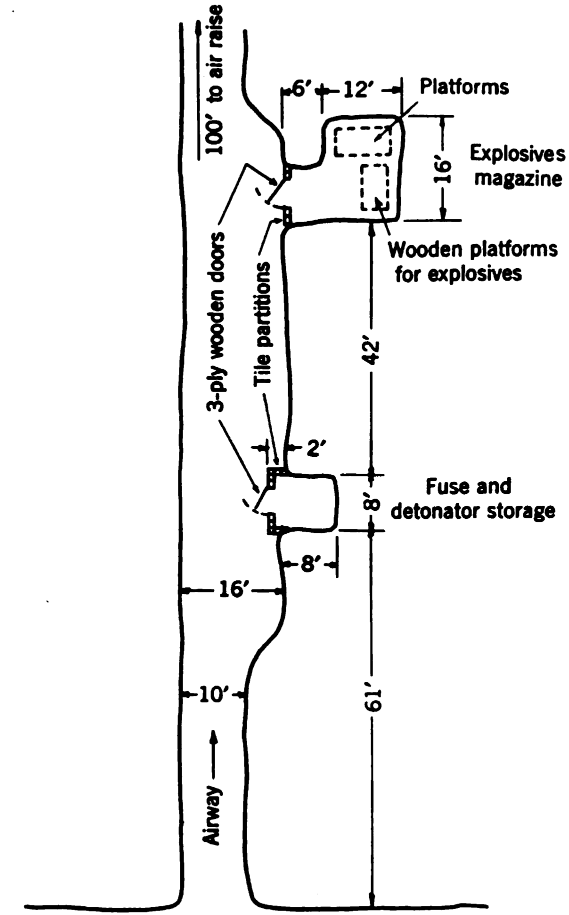

FIGURE 13.- Explosives magazines: Excavation in rock; no timbering required; walls and floor gunited; concrete floors; vaporproof-type lights; electric conductors in conduit; switches located outside.

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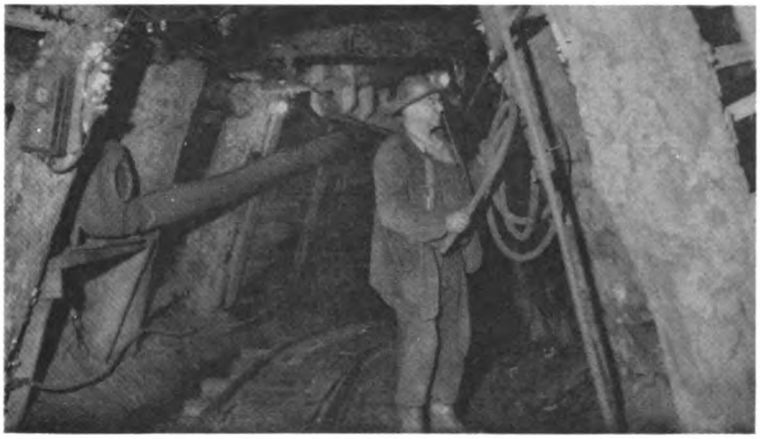

FIGURE 15.- Ventilation of magazines: Blower with flexible tubing discharging in magazine.

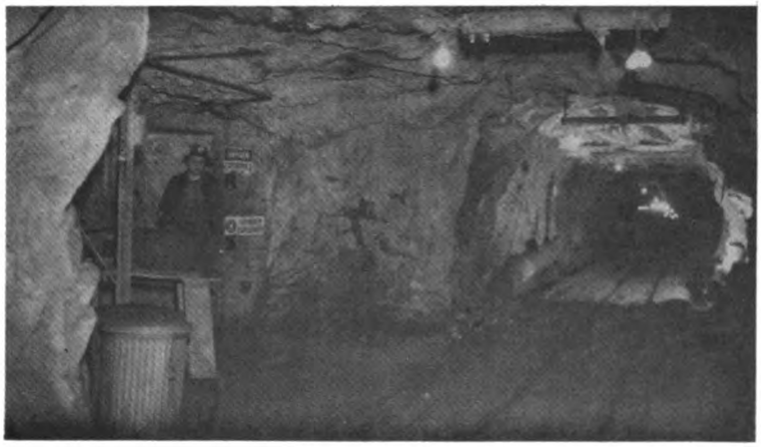

FIGURE 16.- Ventilation of magazines: Blower with rigid duct in concrete floor discharging at rear of magazine.

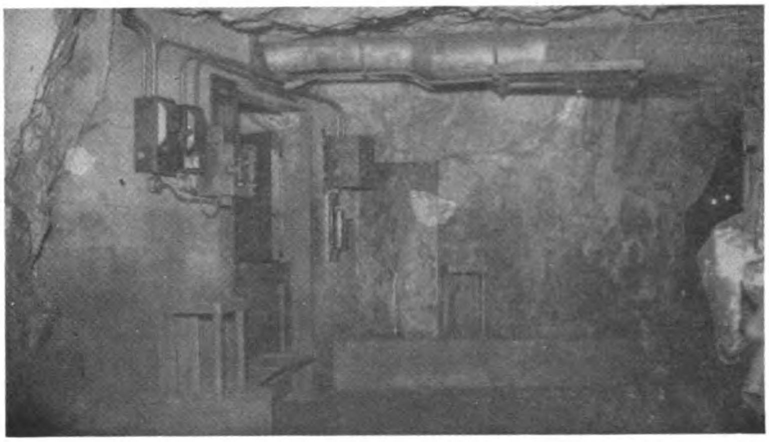

FIGURE 17.- Magazine entrances: Light switches and stands for opening explosives.

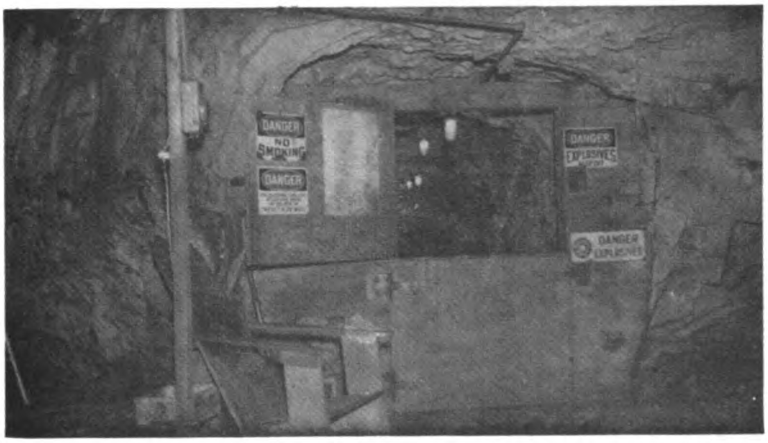

FIGURE 18.- Magazine extrances: Light switches and fixtures.

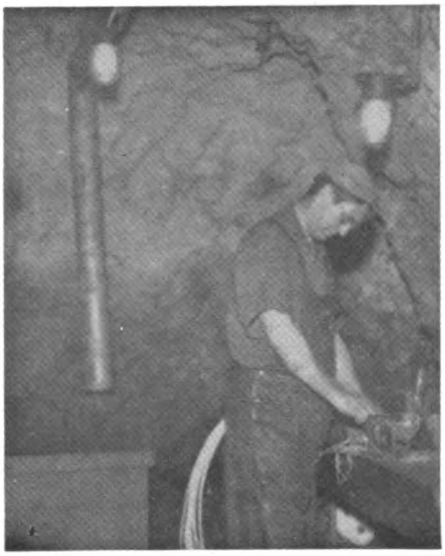

FIGURE 19. - Storage of fuse and detonators: Capping fuse.

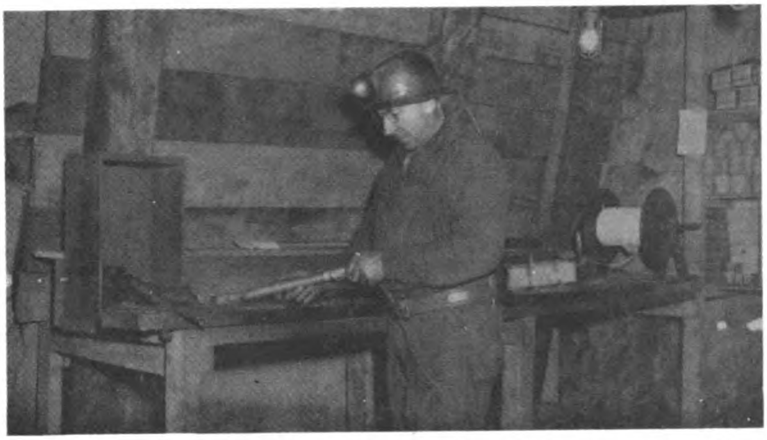

FIGURE 20.- Storage of fuse and detonators: Preparing primer for electric blasting.

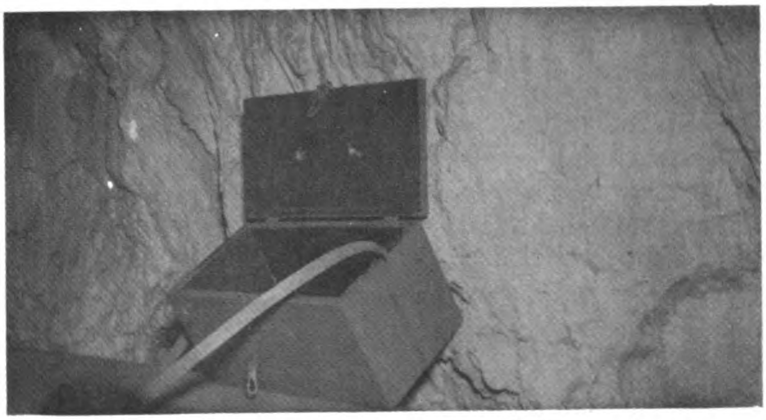

FIGURE 21.- Storage of fuse and detonators: Case for carrying primers.

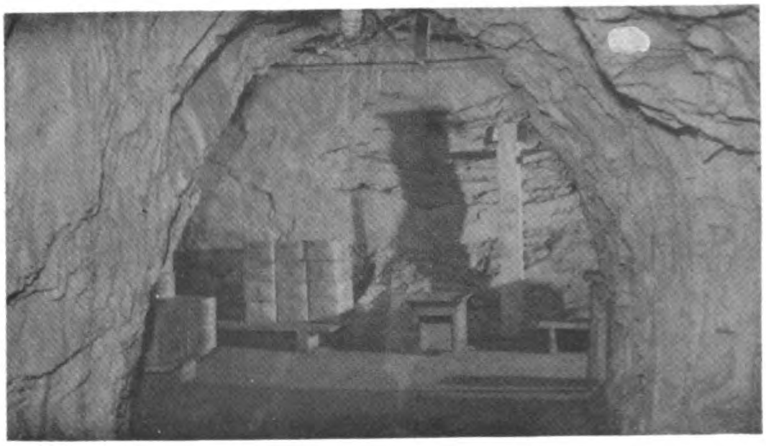

FIGURE 22.- Storage of explosives: Explosives stored on platform.

vaporproof-type lights are provided, and the control switches are outside the magazines. The magazines are ventilated by blowing heated air into them through a duct in the concrete floor. There are three doors: A Dutch door at the entrance beyond which only the magazine attendant is permitted to go, and an ordinary door at the entrance to each of the magazines. All three door frames are set in gunited, 6-inch-tile partitions.

Ventilation

Two means of ventilating magazines are shown in figures 15 and 16. A blower fan and the control switch, mounted between wooden sets on the side of the drift, are shown in figure 15. Air is forced into the magazine through the flexible tubing, which extends through the entrance partition. The hose, which is being coiled and hung on the opposite side of the drift by a miner, is attached to a water line and is intended for use in case of a fire in the immediate approach to the magazine.

A Dutch-door entrance to a magazine is shown in figure 16. The upper half of the door is open, and the magazine attendant is shown behind the lower half, which is closed and functions in this position as a distribution shelf. Metal cans for disposal of daily collections of refuse are shown in the left foreground. The magazine is ventilated by a blower fan located in the nearby fresh-air course, which forces air through a flexible tube connecting to a rigid metal air duct embedded in the concrete floor of the magazine and discharging about 4-feet above the floor level through a wooden duct installed over the metal one in back of the magazine. The air returns through the magazine and discharges through the door when open or through a screened vent over the door.

The primary purpose of figures 17 and 18 is to depict orderly, well-arranged, and secure entrances to magazines in underground mines. The entrances to both magazines are provided with Dutch doors, beyond which only magazine attendants, or other authorized persons, are permitted to enter. Both show the conduit-type of light-wire installation and the control switches outside the magazine. Figure 17 also shows the ventilation tubing entering the concrete partition, two explosives opening stands or stools, a fire extinguisher to the right of the door, and the empty explosives-carrying bags on a rack at the right. Figure 18 shows the grounding wire of the outside-light switch and the vaporproof-type lighting fixtures inside the magazine.

Interior views of two detonator magazines are shown in figures 19 and 20. In figure 19 the attendant is engaged in capping fuses. The ventilation tubing in the background, the box-type magazine for storing detonators, and the vaporproof-type lighting fixture are clearly discernible. In figure 20, the attendant is inserting a primer in a cardboard safety tube.

The primers, after being prepared, are placed in the insulated wooden carrying case shown in figure 21 and carried to the working face for the immediate loading of a round of blast holes.

Figures 5 and 22 are interior views of the same magazine, figure 5 the mode of transporting explosives within the magazine, following transfer from the explosives car and figure 22 the storage of cases of explosives on wooden platforms. The truck shown is constructed entirely of wood. Note in figure 22 the wooden screening box or grizzly in the center background, used in separating the sawdust packing material from the cartridges of explosives when taken from containers, as well as the wooden ventilating-air duct at the right of the box through which the air is discharged about 4 feet above the floor level.

SUMMARY

Although this report covers only a few magazines, known to have been constructed in underground mines of the Lake Superior iron-mining district in 1943 and 1944, considered more than ordinarily satisfactory with respect to location and arrangement, about 92 percent of a probable total of 50 magazines constructed during those 2 years are believed to comply with modern safety standards. The comparative safety of storage, transportation, and handling that has been inaugurated along with the newly provided storages is outstanding when compared to those prevailing previously.

In choosing new magazine sites it is clearly evident that the mine operators have selected locations that are readily accessible to incoming supplies of explosives, as well as for their convenience to working places. The locations are also at safe distances from the supply shaft and from the working places, consistent with the planned mine development. Obviously, a location in stable ground that does not require timbering is preferred. However, ideal conditions embodying the features described are not always available, because of prevailing natural ground conditions and required planning of the mine. The most stable accessible ground is chosen, other conditions having been resolved. As a result, some of the newly constructed magazines are in rock and require no artificial support; some are gunited to prevent moisture from seeping out of the ground, or as a fire-resistive measure; others are supported and lined with wood.

Lighting of these new magazines is more or less standardized; lighting wires are in conduit, vaporproof-type lighting fixtures are in use, and the switches are outside the magazines.

Provision of mechanical ventilation, although frequent, is not general. Where provided, it is by means of a blower fan, located outside of the magazine, forcing air into the magazine through a flexible tube suspended from the roof of the magazine, or through a rigid pipe embedded in the floor.

Heating and drying of air in the magazines have been found necessary in only exceptional cases, because of low temperature or high humidity. For heating and drying, air electrically heated outside the magazine is blown into the magazine in the safest installations; in some mines a well-guarded electric heater is installed in the detonator magazine or in the drift section. Where only drying of the air is required, calcium chloride is used in some cases.

Methods of storing explosives in the magazines vary somewhat; in some the explosives are placed on wooden platforms or racks; in others they are stored in an orderly manner on wooden floors; and in exceptional cases they remain on rubber-tired, wooden transfer trucks provided for use in transporting the explosives from the explosives car into the magazine. The general practice is for the attendant to cut and cap standard lengths of fuse on a wooden bench provided for that purpose in the detonator magazine. A supply of capped fuses, slightly in excess of that needed for one shift or one day, depending on requirements, is stored on an open wooden rack or in a separate wooden cabinet. Occasionally, primers for use in electric blasting are prepared in the detonator magazine and then placed in an insulated carrying case and with little or no delay transported to, and used, at the working face. Detonators, both fuse and electric types, are generally stored in their original containers in wooden box-type magazines, in wooden cabinets, or on open wooden shelves. One case at a time is opened for use as required.

CONCLUSIONS

The majority of the companies operating underground iron-ore mines in the Lake Superior district have shown a commendable trend in improving their practices with regard to locations chosen for new magazine sites, arrangements made in the magazines, and the handling, storage, and use of explosives. Although the storage of explosives in these mines can in many, if not in most, cases be further safeguarded and improved, the outlook for continued and greatly expanded improvement in the transportation, storage, and use of explosives in mines of the Lake Superior region is decidedly hopeful.